Geochronology of the Mons Cupri Archaean Volcanic Centre, Pilbara block, Western Australia

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Abstract

The results of Rb-Sr geochronology on four suites of felsic rocks from the vicinity of the Archaean Mons Cupri volcanic centre in the Pilbara Block of Western Australia are presented. The Caines Well Granite, which represents the foliated granitoid basement to the volcanic complex has a metamorphic age of 2 713 ± 53 Ma and an intial ratio of 0.7040 ± 0.0006 on a closely fitted isochron. A primary age of approximately 3 000 Ma can be calculated using a single stage strontium evolution analysis for this granite. This age is in good agreement with other published data. The Mons Cupri Granite is a massive intrusive body and has an age of 2 366 ± 60 Ma, which is significantly younger than similar granitoids in the East Pilbara. The Mons Cupri Porphyry gives an age of 2 610 ± 80 Ma whereas the Mount Brown Rhyolite has an age of 2 331 ± 42 Ma. These Rb-Sr ages represent updated events rather than the primary ages of the rock units.

Introduction

The Pilbara Block occupies approximately 60 000 km² of the northern part of Western Australia, and is an Archaean granite-greenstone terrain where domal granitic batholiths up to 100 km across are separated by greenstone belts made up of metamorphosed volcanic and sedimentary sequences.

The Archaean greenstone succession comprises folded volcanic and sedimentary units that can be traced across the Pilbara region (Hickman 1983). Two major groups within the layered greenstone succession have been defined—the Warrawoona and Gorge Creek Groups. The Warrawoona Group consists of sequences of tholeiitic and komatiitic lavas and intrusions interlayered with cherty sediments and sequences of calc-alkaline volcanics cut by subvolcanic intrusives; the group is overlain unconformably by the dominantly sedimentary rocks of the Gorge Creek Group (Table 1). These units, together with the Whim Creek Group and the Louden and Negri Volcanics which uncomformably overlie the Gorge Creek Group in the West Pilbara, are called the Pilbara Supergroup by Hickman (1981). The Pilbara Supergroup is in turn overlain by the Fortescue Group which is believed to have been deposited between 2 700 and 2 800 m.a. ago (Trendall 1983).

This paper presents Rb-Sr geochronological results from the mineralised Mons Cupri volcanic centre, which is situated some 100 km south-west of Port Hedland, in the western part of the Pilbara Block.

Geology of the Mons Cupri Area

The Whim Creek Group contains a partly subaerial sequence of calc-alkaline volcanics with associated epiclastic sediments which include shallow and deeper-water facies. Volcanogenic Fe-Cu-Zn sulphide mineralisation occurs within the Whim Creek Group at Whim Creek and Mons Cupri (Marston & Groves 1981).

Fitton *et al.* (1975) defined the Whim Creek Group as a volcanic and sedimentary succession composed of four formations—The Warambie Basalt, Mons Cupri Volcanics, Constantine Sandstone and the Mallina Formation. Hickman (1983) has redefined the Whim Creek Group as consisting, in ascending order, of the Warambie Basalt, Mons Cupri Volcanics and the Rushall Slate, and considers the Constantine Sandstone and the Mallina Formation to be part of the Gorge Creek Group (Table 1). Barley *et al.* (1984) point out that there is some uncertainty as to whether the Whim Creek Group completely post-dates the Gorge Creek Group or contains lateral equivalents of units contained in the Gorge Creek Group. The Whim Creek Group, as defined by Hickman (1983), is confined to the Whim Creek Belt which lies to the south of the Caines Well Granite between the Balla Balla—Mount Negri area and Warambie Homestead.

The Warambie Basalt is a vesicular and amygdaloidal basalt which is the basal formation of the Whim Creek Group. It ranges in composition from basalt to andesite (Hickman 1983).

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Table 1

Stratigraphy of the Upper Pilbara Supergroup (After Hickman 1983)

	Group	Maximum unit	Thickness(m)	Lithology
	Fortescue Group	Mount Roe Basalt	200	Massive to porphyritic columnar and amaygdaloidal basalt
PILBARA SUPERGROUP		Negri Volcanics	200	Basalt and andesite
		Louden Volcanics	1 000	Basalt and ultramafics
	Whim Creek Group	Rushall Slate	200	Slate and phyllite
		Mons Cupri Volcanics	700	Felsic Volcanics
		Warambie Basalt	200	Vesicular basalt
	Gorge Creek Group	Various formations	12 500	Sedimentary rocks
	Warrawoona Group	Various formations	15 600	Tholeitic and komatiitic lavas and intrusions

The Mons Cupri Volcanics crop out in an arcuate belt up to 5 km wide which follows the southern and eastern margins of the Caines Well Granite. The base of the Mons Cupri Volcanics is predominantly dacitic. The lava is fine-grained and contains amygdales filled with quartz, chlorite and carbonate minerals. The sequence is intruded by feldsparphyric dacite plugs. The basal unit is overlain by the Mount Brown Rhyolite Member which is a cream, massive rock, commonly spherulitic and containing fragments of aphanitic felsic lava. The Mount Brown Rhyolite is overlain by a sequence of felsic agglomerate containing thin intercalations of felsic lava and tuff. The agglomerate is the host rock to the Mons Cupri copper deposit. Above the agglomerate finer pyroclastic rocks, tuffaceous sandstone and minor conglomerate marks the top of the Mons Cupri Volcanics (Hickman 1983).

The Rushall Slate is defined by Hickman (1983), and consists of grey slate and phyllite, subordinate flows of andesite and dacite, quartzite, and lenses of felsic tuff.

The geology of the Mons Cupri volcanic centre has been documented by Miller & Gair (1975) and Sylvester (1976). Figure 1 shows the volcanic centre geology as interpreted by Sylvester (1976). The oldest rocks in the area are granitoids of the Caines Well Granite, one of the large granitoid domes which are of granodiorite composition and are commonly strongly foliated. For this study, samples were collected from exposures in the Sherlock River, 25 km west of Mons Cupri.

Resting unconformably upon these granitoids in the vicinity of Mons Cupri, is a sequence of intermediate to felsic metavolcanics, the Mons Cupri Volcanics. The lower units are largely tuffaceous, although amygdaloidal flows have been recorded and are mostly of rhyodacite to rhyolite composition, although some dacites and andesites are present. This sequence has been intruded by feldspar porphyries of rhyolite composition. These have broken surface to produce agglomerates, and the Mons Cupri base metal deposit is associated with one such agglomeratic unit.

The agglomerates are overlain by felsic tuffs, rhyolitic and andesitic flows, thin chert horizons and intercalated slates of the Rushall Slate. This sequence is overlain unconformably by andesitic flows and tuffs of the Negri Volcanics. Intruding all of these rocks is a large plug of spherulitic rhyolite, the Mount Brown Rhyolite, which has produced the domal structure present in the area. Mafic intrusive rocks of the Millindina Complex range in composition from peridotite to granophyre, and are widespread throughout the area, postdating the Mount Brown Rhyolite. The youngest Archaean rocks in the area are subvolcanic adamellite intrusives which have been called the Mons Cupri Granite by Sylvester (1976).

A review of radiometric ages obtained for rock units within the Pilbara Block has been given by De Laeter *et al.* (1981a), and more recently by Blake & McNaughton (1984). Compston & Arriens (1968) reported an age of approximately 2 940 Ma for acid lavas from Whim Creek, although Arriens (1975) stated that this age may need to be revised. However Fitton *et al.* (1975), quoting a personal communication from Arriens, suggested that the age may be between 2 300 and 2 500 Ma.

Two galena samples from the stratiform Salt Creek deposit, within felsic volcanics of the Whim Creek Group, give a model age of 2 950 ± 10 Ma (Richards & Blockley, 1984). The authors argued that the base of the Fortescue Group cannot be younger than 2 800 Ma. Gulson *et al.* (1983) also obtained a Pb-Pb isochron age of 2 940 ± 20 Ma for felsic volcanics at Salt Creek. Richards (1983) also reports an age of 2 930 ± 10 Ma for a galena from Mons Cupri. Fletcher (Pers. comm.) reports a Sm-Nd model age of 3 000 ± 40 Ma from the Mount Brown Rhyolite.

Korsch & Gulson (1986) have recently dated some samples from the Millindinna Complex to give a Sm-Nd whole rock/mineral age of 2 830 ± 20 Ma and a Pb-Pb whole rock age of 2 960 ± 20 Ma. the Millindinna Complex comprises a suite of layered rocks ranging in composition from mafic to ultramafic around the margin of the Caines Well Granite (Fitton *et al.* 1975). The authors

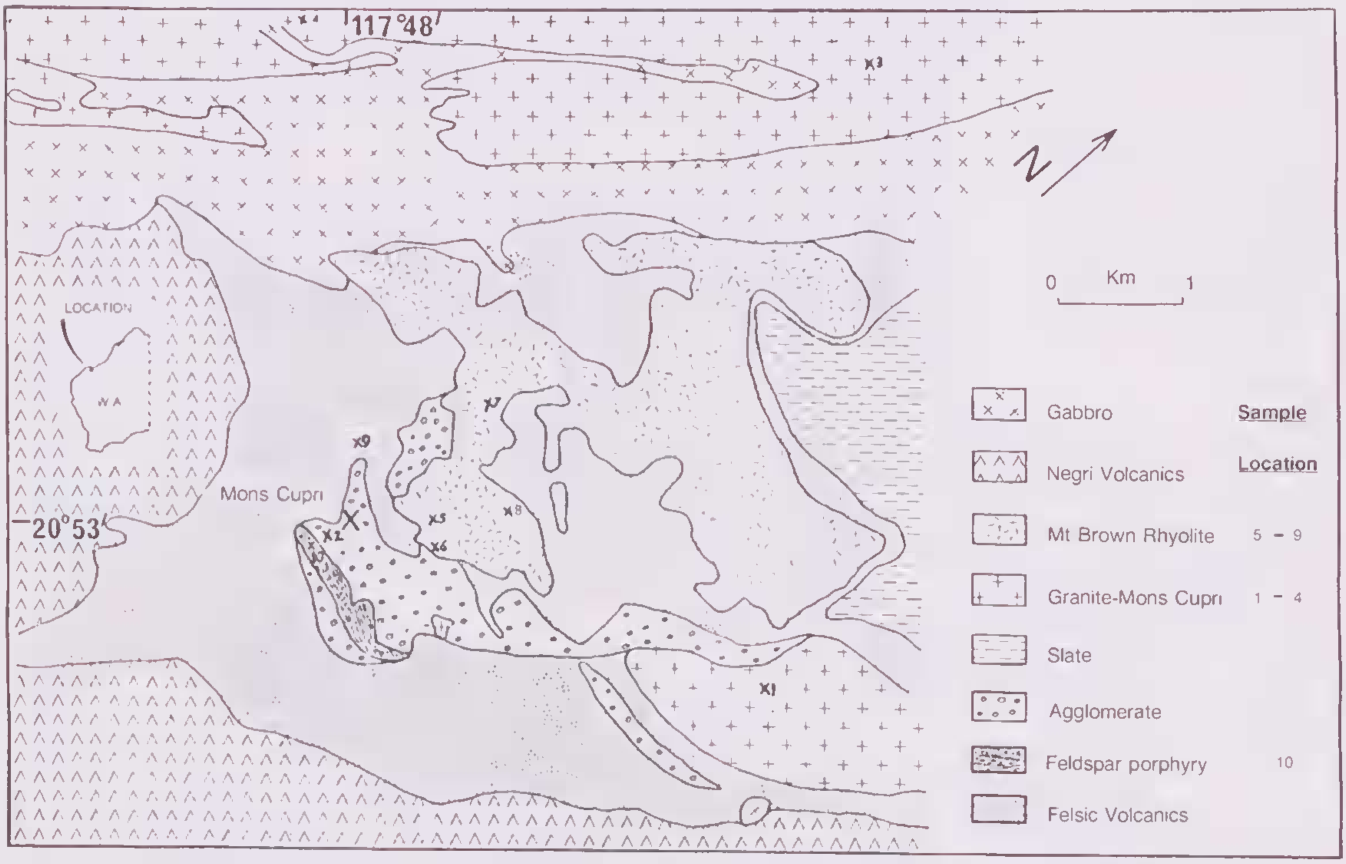

Figure 1—Geology of the Mons Cupri Volcanic Centre showing the sample locations for the Mons Cupri Granite, the Mount Brown Rhyolite and the Mons Cupri Porphyry. Samples from the Caine's Well Granite were collected from the vicinity of the Sherlock River, some 25 km west of Mons Cupri.

point out that the different ages obtained by the two methods probably arises from the limited disperson in lead isotope ratios in the samples, but believe that an age of 2 900 Ma is consistent with the geology and geochronology of the area. Korsch & Gulson (1986) argue that the time difference between the formation of the Whim Creek Group and the emplacement of the Millindinna Complex is probably quite short.

The base of the Warrawoona Group is well established at approximately 3 500 Ma, but the duration of volcanism and the onset of the Gorge Creek sedimentation is still an open question (Blake & McNaughton 1984). However geochronological evidence from zircons from the Boobina Porphyry (Pidgeon 1984) and galena Pb model ages from veins in the upper part of the Warrawoona Group (Richards *et al.* 1981), suggests an end of volcanism at about 3 300 Ma. Thus the Gorge Creek and Whim Creek Groups are constrained between 3 300 Ma and 2 800 Ma.

Analytical Methods

Whole rock major element analyses were carried out by X-ray fluorescence spectrometry using the method of Norrish & Chappel (1967), except for sodium which was determined by atomic absorption spectroscopy.

The experimental procedures for the Rb-Sr analyses are essentially as reported by De Laeter *et al.* (1981b). The value of $^{87}Sr/^{86}Sr$ for the NBS 987 strontium standard measured during this project was 0.71021 ± .00012, normalized to a $^{88}Sr/^{86}Sr$ value of 8.3752. Regression analyses of the data was carried out using the least squares program of McIntyre *et al.* (1966), with a ^{87}Rb decay constant of 1.42×10^{-11}yr. Measured Rb and Sr concentrations and Rb/Sr ratios as determined by X-ray fluorescence spectrometry are listed with the mass spectrometric determinations in Table 2. Errors accompanying the data are at the 95% confidence level although the Rb and Sr concentrations are only accurate to ± 5%.

Results and Discussion

Major element whole rock analyses of some of the samples used for geochronology are listed in Table 3. The results demonstrate that these rocks are relatively unaltered and of comparable composition to typical calc-alkaline rocks of similar silica content.

The nine samples of Caines Well Granite define a well-fitted isochron as shown in Figure 2. The age of these samples is 2713 ± 53 Ma and the initial $^{87}Sr/^{86}Sr$ ratio is 0.7040 ± 0.0006 with a mean square of weighted deviates (MSWD) of 0.51. Two of the samples are mineral separates extracted from the corresponding whole rock samples. Blake & McNaughton (1984) have shown that granitoids and gneisses from batholiths of the Pilbara Block show a range of ages of approximately 3 500 to 2 850 Ma by U-Pb, Pb-Pb and Sm-Nd geochronology, whereas the corresponding Rb-Sr ages tend to be lower. Oversby (1976) detected metamorphic overprinting in similar rocks at 2 751 ± 31 Ma, 2 786 ± 38 Ma and 2 769 ± 13 Ma.

Table 2

Rb-Sr Analytical Data for Mons Cupri Volcanic Centre Samples

Sample	Rb(ppm)	Sr(ppm)	Rb/Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Description
Caines Well Granite						
90223	61	502	0.123 ± 0.002	0.358 ± 0.005	0.71799 ± 0.00019	Recrystallised biotite granodiorite
83995(L)	120	654	0.183 ± 0.002	0.529 ± 0.007	0.72457 ± 0.00031	'Light' mineral separate
83995	75	405	0.188 ± 0.002	0.544 ± 0.007	0.72513 ± 0.00029	Recrystallised biotite granodiorite
90224	115	510	0.228 ± 0.003	0.660 ± 0.008	0.72997 ± 0.00034	Recrystallised biotite granodiorite
90225	61	256	0.236 ± 0.003	0.68 ± 0.01	0.73076 ± 0.00033	Recrystallised biotite granodiorite
90226	71	299	0.240 ± 0.003	0.70 ±0.01	0.73164 ± 0.00022	Recrystallised biotite hornblende granodiorite
84065	115	380	0.300 ± 0.004	0.87 ± 0.01	0.73864 ± 0.00025	Recrystallised biotite granodiorite
84066(L)	204	421	0.484 ± 0.005	1.40 ± 0.02	0.75862 ± 0.00024	'Light' mineral separate
84066	170	265	0.640 ± 0.007	1.86 ± 0.02	0.77703 ± 0.00025	Recrystallised biotite granodiorite
Mons Cupri Granite						
84000	130	180	0.72 ± 0.007	2.08 ± 0.02	0.78114 ± 0.00031	Recrystallised sericitic, chloritic adamellite
83996	160	110	1.45 ± 0.02	4.19 ± 0.04	0.85435 ± 0.00033	Sericitised and carbonated adamellite
83998	70	37	1.89 ± 0.02	5.64 ± 0.05	0.91394 ± 0.00029	Recrystallised chloritic adamallite
84003	133	49	2.69 ± 0.03	7.97 ± 0.08	0.98399 ± 0.00025	Recrystallised chloritic adamallite
83999	75	22	3.41 ± 0.03	10.0 ± 0.1	1.06753 ± 0.00033	Recrystallised chloritic adamallite
* 84002	334	30	10.9 ± 0.1	34.3 ± 0.3	1.63373 ± 0.00035	Sericitised, silicified and chloritised adamellite
84001	277	23	11.9 ± 0.1	38.7 ± 0.4	2.03424 ± 0.00040	Sericitised, chloritised and carbonated adamellite-granite
Mt. Brown Thyolite						
84004	30	165	0.178 ± 0.002	0.52 ± 0.05	0.73118 ± 0.00015	Chloritic, fine-graned rhyolite
83987(L)	265	178	0.68 ± 0.007	1.98 ± 0.02	0.77990 ± 0.00014	'Light' mineral separate
83987	85	120	0.71 ± 0.007	2.03 ± 0.02	0.78209 ± 0.00018	Massive spherulitic rhyolite
83992	80	90	0.89 ± 0.009	2.53 ± 0.03	0.79711 ± 0.00025	Slightly sericitised rhyolite
83993	110	115	0.95 ± 0.01	2.77 ± 0.03	0.80698 ± 0.00023	Massive, fine-grained rhyolite
83988	125	130	0.98 ± 0.01	2.86 ± 0.03	0.81146 ± 0.00022	Massive spherulitic rhyolite
83989	135	40	3.38 ± 0.03	9.65 ± 0.1	1.03813 ± 0.00031	Sericitised and carbonated spherulitic rhyolite
Mons Cupri Porphyry						
84010	60	160	0.38 ± 0.004	1.07 ± 0.01	0.74171 ± 0.00025	Brecciated, chloritised and carbonated feldspar porphyry
84017	84	109	0.79 ± 0.008	2.30 ± 0.02	0.79126 ± 0.00018	Silicified feldspar porphyry
84013	130	155	0.90 ± 0.009	2.62 ± 0.03	0.80184 ± 0.00029	Brecciated, sericitised feldspar porphyry
84012	80	45	1.78 ± 0.02	5.24 ± 0.05	0.89758 ± 0.00031	Brecciated, sericitised chloritised feldspar porphyry
84015	208	73	2.87 ± 0.03	8.5 ± 0.09	1.02034 ± 0.00032	Slightly chloritic feldspar porphyry
84014	171	47	3.65 ± 0.04	11.0 ± 0.01	1.12206 ± 0.00035	Sericitised feldspar porphyry

* This sample is not included in the isochron for the Mons Cupri Granite.

Table 3

Representative analyses of calc-alkaline volcanics and associated high level intrusives from the Mons Cupri Volcanic Centre

	Caines Well Granite			Mons Cupri Granite				Mount Brown Rhyolite					Mons Cupri Porphyry		
	83995	84065	84066	84000	83996	82998	83999	83987	83992	83993	83988	83989	84010	84013	84012
SiO_2	73.55	73.37	70.13	72.15	65.57	76.20	76.87	73.88	77.05	75.41	76.39	76.19	70.54	77.39	67.45
TiO_2	0.16	0.16	0.17	0.25	0.33	0.32	0.32	0.50	0.45	0.48	0.45	0.45	0.56	0.56	0.68
Al_2O_3	14.66	16.05	16.30	14.13	15.07	11.15	10.99	12.87	12.41	12.67	12.61	11.50	12.67	12.33	13.59
Fe_2O_3	0.30	1.00	2.39	0.76	0.62	1.42	1.13	0.38	0.30	0.43	0.04	0.71	0.35	0.49	0.71
FeO	0.91	0.01	0.01	1.42	3.03	1.66	1.86	1.40	0.71	0.33	0.75	1.56	3.68	0.53	5.93
MnO	0.02	0.03	0.03	0.03	0.06	0.05	0.05	0.05	0.03	0.03	0.04	0.04	0.08	0.04	0.10
MgO	0.41	0.18	0.62	0.63	2.95	0.19	0.18	0.26	0.17	0.16	0.15	0.89	0.80	0.71	1.40
CaO	1.97	1.40	2.17	1.35	1.52	0.70	0.66	1.29	0.31	0.91	1.26	1.34	1.25	0.48	1.07
Na_2O	4.75	4.45	4.72	3.90	0.57	3.66	3.39	5.33	4 78	4.74	3.57	0.18	4.14	3.22	1.96
K_2O	2.76	3.94	2.91	4.37	5.36	3.91	4 13	2.95	3.05	3.94	3.62	4.35	3.52	2.52	3.19
P_2O_5	0.05	0.04	0.03	0.09	0.13	0.03	0.03	0.13	0.12	0.13	0.11	0.12	0.12	0.05	0.14
LOI	0.90	0.77	0.74	1.66	4.72	0.67	0.67	1.71	1.03	1.40	1.06	0.34	2.53	2.07	3.62
Total	100.44	101.40	100.22	100.74	99.93	99.96	100.28	100.75	100.41	100.63	100.05	97.67	100.24	100.39	99.84

Strontium evolution analysis of the data from Caines Well Granite suggests a mantle evolution age of approximately 2 975 Ma assuming single stage evolution. This value has been calculated from the measured age of 2 713 Ma and the initial ratio of 0.7040, assuming a $^{87}Rb/^{86}Sr$ ratio which is the arithmetic mean of the suite of samples. Mantle Sr evolution was assumed to be linear from 0.6990 at 4 600 Ma to 0.7040 at present (Faure & Powell 1972). The primary Rb-Sr age of approximately 2 975 Ma is in good agreement with ages determined by more robust geochronological techniques on Pilbara Block Batholiths.

Six of the seven Mons Cupri Granite samples fall on an isochron shown in Figure 3. The model 1 age and initial ratio is 2 430 ± 25 Ma and 0.7089 ± 0.0017 respectively. However the MSWD of 26 indicates a poor fit, and a model 3 age and initial ratio of 2 366 ± 60 Ma and 0.7156 ± 0.011 respectively are to be preferred.

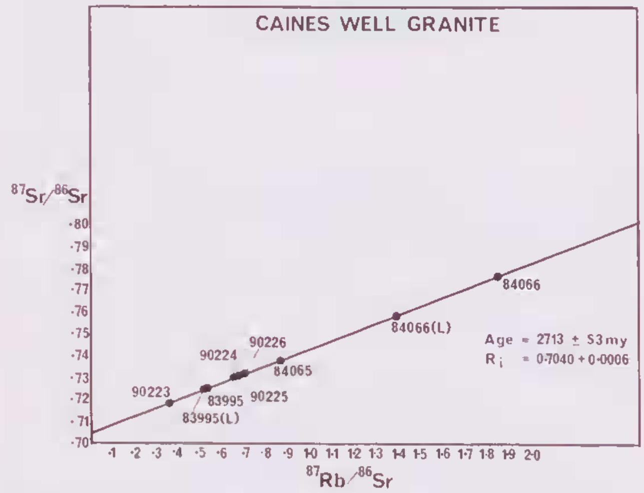

Figure 2—$^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram for samples from Caine's Well Granite.

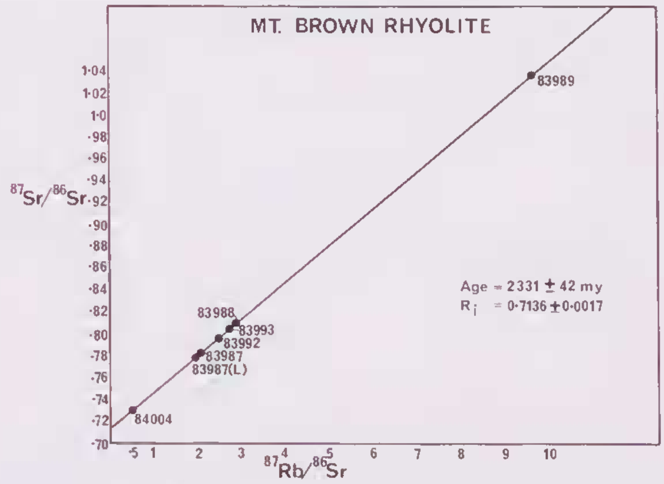

Figure 4—$^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram for samples from Mount Brown Rhyolite.

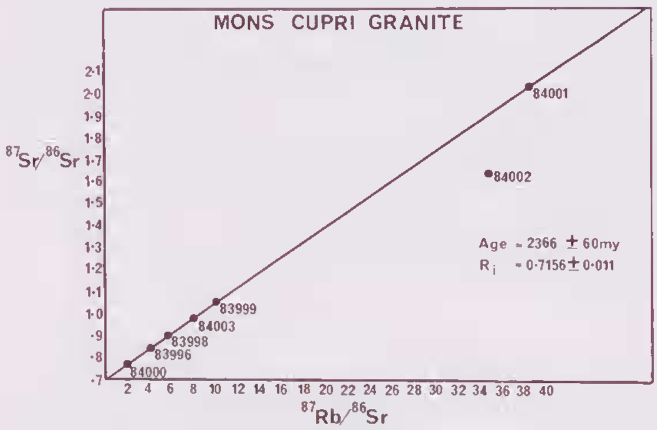

Figure 3—$^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram for samples from Mons Cupri Granite.

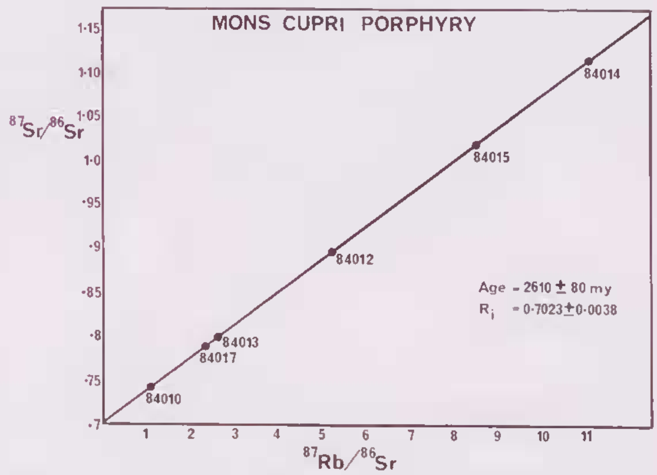

Figure 5—$^{87}Sr/^{86}Sr$ vs $^{87}Rb/^{86}Sr$ diagram for samples from Mons Cupri Porphyry.

The Mons Cupri Granite is one of the young massive intrusive bodies which are common throughout the Pilbara Block. It differs from the Caines Well Granite in being of adamellite composition and having higher Rb/Sr ratios. The age of 2 366 ± 60 Ma is somewhat younger than similar granitoids in the East Pilbara, where dates of 2 670 ± 95 Ma and 2 606 ± 128 Ma have been reported (De Laeter & Blockley 1972, De Laeter *et al.* 1975). The Moolyella and Cooglegong adamellites are intermediate level structural types, whereas the chemistry and petrography of the Mons Cupri Granite show it to be of a high level subvolcanic type.

The Mount Brown Rhyolite samples give a Model 1 age of 2 331 ± 27 Ma and an initial ratio of 0.7136 ± 0.0008 (Figure 4). The MSWD of 3.6 indicates a reasonably good fit of the seven samples, but a more accurate estimate of the age and initial ratio would be given by the Model 3 values of 2 331 ± 42 Ma and 0.7136 ± 0.0017 respectively. The data may reflect the local outpouring of the lowermost Fortescue Group volcanics (Mount Roe Basalt), as suggested by Oversby (1976), but more likely relates to the D4 or D5 deformations documented by Hickman (1983). The Rb-Sr age is significantly less than the Sm-Nd model age of 3 000 ± 40 Ma reported by Fletcher (Pers. comm.).

The feldspar porphyry samples fit an isochron (Figure 5), which gives a Model 1 age of 2 617 ± 28 Ma and initial ratio of 0.7020 ± 0.0011. However the samples give a MSWD of 9.1, and a more realistic estimate would be a Model 4 age and initial ratio of 2 610 ± 80 Ma and 0.7023 ± 0.0038 respectively. The Rb-Sr age of the porphyry from Mons Cupri is intermediate in value between the ages obtained for the Caines Well and Mount Brown Rhyolite. Although this is consistent with the geology of the region, it must be pointed out that since the Rb-Sr isochron ages are updated ages, the sequence of measured ages do not represent the ages of emplacement of the various rock units.

The calculated primary age of the Caines Well Granite of approximately 3 000 Ma is however, consistent with the other published age data for the Salt Creek deposit and the Millindinna Complex.

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